IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF NORTH CAROLINA
WESTERN DIVISION
CASE NO. 5:21-cv-0137-FL

360 VIRTUAL DRONE SERVICES LLC and MICHAEL JONES, Plaintiffs, v. ANDREW L. RITTER, in his official capacity as Executive Director of the North Carolina Board of Examiners for Engineers and Surveyors; and JOHN M. LOGSDON, JONATHAN S. CARE, DENNIS K. HOYLE, RICHARD M. BENTON, CARL M. ELLINGTON, JR, CEDRIC D. FAIRBANKS, BRENDA L. MOORE, CAROL SALLOUM, and ANDREW G. ZOUTWELLE, in their official capacities as members of the North Carolina Board of Examiners for Engineers and Surveyors, Defendants.	)	**DEFENDANTS' DISCLOSURE OF EXPERT TESTIMONY (Rule 26(a)(2))**

Pursuant to Rule 26(a)(2) of the Federal Rules of Civil Procedure and pursuant to the Case Management Order, Defendants hereby disclose the identity of the expert witness they may use at trial to present evidence under Federal Rule of Evidence 702, 703, or 705.

1. Mark S. Schall, CP, PLS, PPS, SP
Spatial Data Consultants, Inc.
1008 Hutton Lane, Suite 109
High Point, North Carolina 27262

Mr. Schall was specially retained for purpose of this litigation. The report of

Mark S. Schall, CP, PLS, PPS, SP is produced herewith. Further, produced herewith is a copy of Mr. Schall's Curriculum Vitae, a list of all cases in which, during the previous 4 years, Mr. Schall testified as an expert at trial or by deposition, and a statement of the compensation to be paid for the study and testimony in the case.

This the 30th day of November, 2021.

GRAEBE HANNA & SULLIVAN, PLLC

/s/ Douglas W. Hanna
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CERTIFICATE OF SERVICE

I hereby certify that I have this day served a copy of the **DEFENDANTS' DISCLOSURE OF EXPERT TESTIMONY (Rule 26(a)(2))** upon all parties to this action by email addressed as follows:

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This the 30th day of November, 2021.

/s/ Douglas W. Hanna
Douglas W. Hanna, NCSB #18225

Report of Mark S. Schall, CP, PLS, PPS, SP

Attorney Douglas W. Hanna, representing The North Carolina Board of Examiners for Professional Engineers and Land Surveyors (NCBELS), has retained me to give expert testimony or opinions on the following:

- What is Photogrammetry?
- How does Photogrammetry Work?
- My Experience in Photogrammetry
- Using Unmanned Autonomous Vehicles (UAV's) or Drones as a Tool for Photogrammetry
- My Experience using Drones as a Tool for Photogrammetry
- Why Land Surveying, most specifically Photogrammetry, as the North Carolina Legislature has designated the practice of Land Surveying as a profession, is regulated by NCBELS.
- The Purpose of Regulating Land Surveying and Photogrammetry
- Specific Issues Raised in the Complaint

About Mark S. Schall

Currently, I'm the Chief Professional Officer (CPO) and Professional Land Surveyor (PLS) in responsible charge at Spatial Data Consultants, Inc. (SDC), a regional Geospatial Consulting firm specializing in Surveying, Photogrammetry, Remote Sensing and GIS, including Unmanned Autonomous Systems (UAS) surveys. My professional experience spans from 1979 to present, I have approximately 42 years of applied and professional experience and expertise in the fields of Surveying and Photogrammetry.

Prior to founding SDC in February of 1996, I gained approximately 17 years of production and project management experience in Land Surveying and Photogrammetry for regional, national and international consulting firms headquartered in the eastern United States.

My professional credentials also include the following certifications, registrations and affiliations.

- American Society of Photogrammetry and Remote Sensing (ASPRS)
    - Certified Photogrammetrist #950, 1994
- The North Carolina Board of Examiners for Professional Engineers and Land Surveyors
    - Professional Land Surveyor L-4019, 1999
- The South Carolina State Board of Registration for Professional Engineers and Land Surveyors
    - Photogrammetric Surveying #22679, 2003
- Commonwealth of Virginia Board for Architects, Professional Engineers, Land Surveyors, Certified Interior Designers and Landscape Architects
    - Surveyor Photogrammetrist #75, 2010
- Approximately 437.5 hours of Professional Development Hours (PDHs) of education required to maintain professional certifications and registrations.
- North Carolina Society of Surveyors (NCSS), Sustaining Member
- Board of Director, and Past President for the NCSS Education Foundation, served 9 years.
- Instructor, NCSS Institute for Professional Continuing Education, teaching Photogrammetry competency courses.
- Professional Land Surveyor (PLS) in responsible charge for the North Carolina (NC) Statewide Orthoimage Program, from 2012 to present, SDC as a Prime Vendor. This annual reoccurring project is funded by the NC E-911 Board, and facilitated by NC Information Technology Services (ITS) Center for Geographic Information and Analysis (NCCGIA).

In preparing this report and my opinions herein, I'm relying on my 42 years of applied and professional experience in Photogrammetry, Land Surveying and other Geospatial disciplines. I reserve the right to amend this report if additional information is revealed during case findings. I have never testified as an expert at trial or by deposition at any time in my career.

In consideration of the health, safety and welfare of the public in the State of North Carolina, I have prepared this report pro bono. In addition, any expert testimony by deposition that may be required of me will also be provided pro bono.

What is Photogrammetry?

Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena (Wolf and Dewitt, 2000; McGlone, 2004).

Photogrammetry is nearly as old as photography itself. Since its development approximately 150 years ago, photogrammetry has moved from a purely analog, optical–mechanical technique to analytical methods based on computer-aided solution of mathematical algorithms and finally to digital or softcopy photogrammetry based on digital imagery and three-dimensional (3D) computer vision, which is devoid of any optical-mechanical hardware.

Photogrammetry is primarily concerned with making precise measurements of three-dimensional (3D) objects and terrain features from two-dimensional (2D) photographs. Applications include the measuring of coordinates; the quantification of distances, heights, areas, and volumes; the preparation of topographic maps; and the generation of digital elevation models and orthophotographs (Aber, Marzolff and Ries, 2010).

Although similar to each other, following are some definitions of Photogrammetry from other sources…

Founded in 1934, The American Society for Photogrammetry and Remote Sensing (ASPRS) is an American learned society devoted to photogrammetry and remote sensing. It is the United States member organization of the International Society for Photogrammetry and Remote Sensing (ISPRS).

ASPRS defines Photogrammetry as… "the art, science, and technology of obtaining reliable information about physical objects and the environment, through processes of recording, measuring, and interpreting images and patterns of electromagnetic radiant energy and other phenomena."

Wikipedia, the free online encyclopedia defines Photogrammetry as… "the science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena."

Merriam-Webster, a Dictionary since 1828, defines Photogrammetry as… "the science of making reliable measurements by the use of photographs and especially aerial photographs (as in surveying)."

From my own experience and perspective…

Photogrammetry is a discipline of Professional Land Surveying, Land Surveying or Surveying, regardless of how one wishes to term it. Where in Land Surveying, the Surveyor goes into the field to locate, measure and record accurate survey data or useful information; in Photogrammetry, the Surveyor obtains imagery, aerial or terrestrial, most often aerial, and brings the field into the office environment, then uses Photogrammetric practices and processes to locate, measure and record accurate survey data or useful information from the imagery. This is the simplest explanation or analogy I can offer.

How does Photogrammetry Work?

In the context of this report, I can't begin to scratch the surface of how complex and continuously developing a technology Photogrammetry is, with its evolving techniques and high-level mathematical principles. This is the primary reason why Photogrammetry is licensed and regulated under Land Surveying in NC and requires the Licensed Professional to continue his/her education in the form of Professional Development Hours (PDHs) throughout their career, typically on an annual basis.

Following is a very fundamental description of how Photogrammetry works…

Photogrammetry is a three-dimensional (3D) coordinate measuring technique that uses photographs or images, most often from an airborne platform, as the essential source for locating, measuring and recording survey data or useful information. Throughout the history of Photogrammetry airborne platforms have ranged from balloons and kites, to fixed wing aircraft, rotor wing aircraft, satellites and unmanned autonomous vehicles (UAV), or more commonly known as drones. The airborne platform used to collect the imagery doesn't matter, the subsequent Photogrammetric workflow to achieve the desired survey data or useful information is exactly the same regardless of how the imagery is acquired.

The fundamental principle used in photogrammetry is triangulation. When using aerial imagery, it's often referred to as aero-triangulation or aerial triangulation. By taking photographs from at least two different locations, lines of sight, also called image rays, can be developed from each camera principal point to points on the object. These image rays, due to their optical nature, are mathematically intersected to produce the three-dimensional (3D) coordinates of the points being measured. Triangulation is also the principle used by theodolites for coordinate measurements in Land Surveying. Triangulation is also how the two human eyes work together to gauge distance which is called depth perception.

Responsible Photogrammetric practice includes the use of metric cameras and sensors that are engineered, designed and manufactured specifically for surveying and mapping applications. A metric camera is very high quality, very expensive, and virtually distortion free. A metric camera utilizes a leaf shutter, has a focal length and internal dimensions which are exactly known through calibration, and can maintain calibration for long periods of time over numerous airborne missions, thus providing accurate, repeatable and dependable results for triangulation and survey data extraction time after time.

A modern metric digital camera may often be called a sensor because they're digital in nature however, another example of a metric sensor used for terrestrial, mobile and airborne surveys is LiDAR, which is an acronym for Light Detection and Ranging. Lidar is a method for determining ranges by targeting an object with a laser and measuring the time for the reflected light to return to the receiver (Wikipedia). LiDAR sensors can vary widely in quality, accuracy and cost, and are utilized in a wide variety of industries including surveying and mapping, manufacturing automation, agriculture, automotive safety and many others.

Over the past 50 years, new metric airborne cameras and sensors for commercial Photogrammetry and Remote Sensing surveying operations have ranged in cost from $300,000.00 to as much as $1,500,000.00. This doesn't include the software and internal infrastructure required for developing or post processing the imagery or other types of sensor data. These cameras and sensors are essentially surveying instruments which were engineered, designed and manufactured specifically for the purpose of producing distortion free imagery and other types of remotely sensed data suitable for Photogrammetric surveying.

My Experience in Photogrammetry

I first started my Photogrammetry career in 1979 at the Ralph L. Woolpert Company (now Woolpert, LLP), an international Engineering, Land Surveying and Geospatial consulting firm headquartered in Dayton, Ohio. During my tenure at Woolpert, I was taught the basic principles of Photogrammetry and Land Surveying by highly trained and skilled Photogrammetrists and Surveyors. This was during the Analog development stage of Photogrammetry. Aero-triangulation was a manual process of locating, marking and measuring pass, tie and control points, also known as "bridging" in those days. Planimetric and topographic maps for engineering applications were manually drawn on mylar manuscripts by hand using projection or optical mechanical stereo-plotting devices, the imagery used was captured with analog metric aerial cameras using acetate based aerial film for distortion free imagery. Computers and or software had not yet been developed or integrated into Photogrammetry procedures and or processing.

From 1985 through 1995 I worked for several other regional, national and international Geospatial Consulting firms across the eastern United States. During this period of my career, I widened my experience in Photogrammetry to include project technical planning, production supervision and project management. This was during the Analytical development stage of Photogrammetry. Imagery was still being collected using analog metric aerial cameras using acetate based aerial film for distortion free imagery however, the development of main frame computers allowed for the development of block adjustment software, which greatly improved aero-triangulation, and the analytical stereo-plotter. Analytical stereo-plotters use a mathematical projection based on the co-linearity (two vectors pointing in the same direction) equation model. The mechanical element of the instrument is a very accurate, computer-controlled device that compares two photographs simultaneously (Wikipedia).

In February of 1996, I founded Spatial Data Consultants, Inc. (SDC), a regional Land Surveying and Geospatial consulting firm located in High Point, NC. From 1996 to present, I've witnessed and experienced the transition of Analytical Photogrammetry into Digital Photogrammetry. Film based metric analog aerial cameras have been replace with digital airborne sensors, both active and passive, for imagery, LiDAR or other remote sensing data. Although still used by some Photogrammetrists, analytical stereo plotters have been replaced by PC base Softcopy Photogrammetry software platforms utilizing specialized graphics cards, monitors, emitters and glasses allow for three-dimensional (3D) stereo viewing for Photogrammetric data collection and post processing.

During my 42-year career, Photogrammetry has been a constantly changing and progressive science within Land Surveying, requiring ongoing education and training in order to gain current technical knowledge and expertise. In my experience, Photogrammetry has always been viewed and practiced as a professional vocation under the guise of Land Surveying. I've always practiced Photogrammetry emphasizing professionalism, ethical conduct, compliance with legislated standards of practice; while observing regulatory and professional licensing requirements; in consideration of the health, safety and welfare of the general public.

Using Drones for Photogrammetry and Surveying

Modern drones equipped with cameras were first developed in the early 1980's for military applications. Hobbyist drones began to emerge in the early 2000's out of the remote control (RC) model aircraft community. Consumer off the shelf (COTS), or recreational drones became available around 2006, with popularity in the United States beginning to increase around 2015.

UAVs or drones offer an alternative aviation platform or tool for Photogrammetry besides fixed wing or rotor wing aircraft however, this doesn't necessarily mean lower cost for an acquisition system or lower project costs for the client. Drones and payloads engineered, designed and manufactured specifically for Surveying and Photogrammetry can cost upwards of $300,000.00 or more, compared to a COTS drone and payload which typically cost under $500.00, but can range in cost from under $500.00 to $1,500.00. Drones for other professional applications can cost tens of thousands of dollars, prices vary widely.

The availability of COTS drones along with the development of inexpensive, sometimes free, Structure from Motion (SfM) Photogrammetry software which allows for "black-box" processing, unsupervised when using internet cloud-based post processing services, or by unskilled users, has created an overwhelming surge in the popularity of Photogrammetry since 2015.

If it weren't for the introduction of low-cost drones and SfM post processing software the UAS gold rush within the Photogrammetry and Surveying industries we've experienced in recent years wouldn't have taken place. Mainstream surveying equipment manufacturers like Trimble, Leica, Topcon, Javad, Riegl, and many others, all started developing drone surveying systems and software as another surveying and mapping tool to market to their traditional client demographic, which were Surveyors, Engineers and Photogrammetrists, not recreational or hobbyist drone enthusiasts.

From around 2018 to present the development curve of drone sensors and post processing software has flattened. Currently, there are ample UAS systems available that have been engineered, designed and manufactured specifically for Photogrammetric Surveying, that can provide accurate, reliable and repeatable results.

My Experience Using Drones for Photogrammetry and Surveying

My experience with using a UAV or drone for Photogrammetry and Surveying began in early 2016 as a reaction to the overwhelming promotion and hype of drone photogrammetry and surveying within our industry. At that time, mainstream survey equipment and drone manufacturers were developing drone surveying systems and software, aggressively marketing them to Professional Surveyors and Engineers in an attempt to add the element of Photogrammetry to their everyday practice.

For myself, as a Professional Photogrammetric Surveyor, the appearance of drones in the industry was simply another airborne platform or tool we could utilize when the physical or technical scope of a project wasn't practical for a fixed wing or rotor wing aircraft however, drones have weight and payload limitations, so the most critical aspect of using a drone as an aviation tool for Photogrammetry and Surveying would be the cameras or sensors being used to collect imagery or other remote sensing data since mainstream metric airborne cameras and sensors for Photogrammetry and Surveying were designed for fixed wing or rotor wing aviation platforms.

During 2016 and 2017, with the assistance of Staff Members, Peers, Manufacturers and Clients, we began testing various COTS drone surveying systems and SfM Photogrammetry software applications to determine if we could achieve accurate, reliable and repeatable results compared to our proven Photogrammetric workflows using airborne imagery collected with metric airborne cameras or sensors from fixed wing or rotor wing aviation platforms, meeting Client expectations, and in compliance with regulated surveying and mapping standards.

The drone surveying systems we initially tested during this period were comprised of COTS drones and cameras, all of which didn't measure up when we compared the drone system survey data to verified field survey data or data derived from our standard photogrammetric procedures, which had also been validated by statistical analysis using surveyed ground control and check points. We attributed the inaccuracy of the SfM processed drone survey data to the following technical or physical limitations.

Technical Limitations

1) The COTS cameras we tested consisted of digital single-lens reflex camera (DSLR) cameras which aren't metric, or in other words, aren't calibrated by the manufacturer. Each time the camera was turned on the calibration changed.
2) The COTS cameras we tested utilized a rolling shutter. A rolling shutter camera scans the pixels of each image, introducing pixel shifts with the movement of the camera over the duration of the scan. Pixel displacement in the images caused feature matching problems and inaccurate camera parameters during SfM Photogrammetry post processing.
3) The COTS cameras we tested didn't have a precise center of exposure pulse for geocoding each image with accurate relative coordinates.
4) The COTS cameras we tested weren't coupled with survey grade GPS for geocoding each image with accurate absolute coordinates.
5) The center of exposure pulse precision and non-survey grade GPS coupled with the COTS cameras we tested didn't produce post processed data within the manufacturers advertised accuracy for direct georeferencing. We tested a number of scenarios introducing surveyed ground control into the post processing, from minimal to saturated configurations until we achieved somewhat accurate results.

Physical Limitations

1) Vegetation caused problems during SfM post processing. Dense brush and tree canopy yielded incomplete triangulation which couldn't be corrected by manual inspection and measuring due to extremely small image footprints and the fact there were no visible locations in the imagery to accurately measure triangulation tie or pass points, also known
2) Vegetation on site caused problems during SfM post processing. Grass and weeds yielded point cloud elevation points which didn't represent bare earth or ground elevation. The SfM Photogrammetry software didn't allow for visual 3D inspection of the point cloud data for manual review and correction by a highly trained and skilled Photogrammetric Technician as our standard 3D Photogrammetric software platform and workflow allows for.
3) Other site conditions such as surface motion, highly reflective surfaces and consistent surface patterns all caused pixel matching problems during SfM post processing. These conditions might include trees moving in the wind, moving or static water, highly reflective surfaces, row crops, new asphalt or concrete.

The extensive tests we conducted between 2016 and 2017 validated my decision to delay our implementation of drones into our acquisition and product development workflows. I felt the development of the systems, primarily using COTS components, and the software for post processing, were underdeveloped and being oversold by the Developers. In regards to Photogrammetry, Surveying and Mapping, everyone was jumping on the drone bandwagon prematurely in an attempt to ride the initial wave of commercial opportunities.

In late 2017, I made the decision to seek out a drone manufacturer to assist us in designing and developing a UAV Surveying system that would use components that were engineered, designed and manufactured specifically for Surveying and Mapping applications. We wouldn't try to implement any drone, camera or sensor technology for commercial operations that was meant for the recreational consumer or hobbyist.

In early 2018 I reached out to Microdrones, an international company based in Germany, recently acquired by GE, with support facilities in Toronto, Canada and Atlanta, GA, to inquire about their interest in developing a fully integrated UAV system for Photogrammetry. Microdrones agreed to work with SDC to codevelop such a system which is now known as the mdLiDAR3000.

From February through July of 2018 SDC staff aided in the development of the mdLiDAR3000 hardware, flight control and management system and the data post processing software. SDC took delivery of the first mdLiDAR3000 drone Photogrammetry Mapping System in August of 2018. The basic composition of the system was as follows…

1) Microdrones md4-3000 Heavy Lift Drone
2) Riegl MiniVUX-1UAV LiDAR Sensor (LiDAR manufactured specifically for surveying)
3) Sony RX1RII Digital Camera (affixed lens, mechanical leaf shutter with precise exposure pulse)
4) Trimble APX-20 UAV DG (military and survey grade GNSS-INS for direct georeferencing)

After three years of research, testing and development, and a financial investment of nearly $500,000.00 we were ready and confident to begin offering drone Photogrammetry to our customer demographic. We were the first Geospatial company to commercially operate the Microdrones mdLiDAR3000 drone Photogrammetry system worldwide, and would have the distinction of being the only commercial operator until Microdrones announced the mdLiDAR3000 product release on September 29, 2018.

From August 2018 to present, SDC has successfully accomplished over eight hundred (800) commercial drone missions, in compliance with FAA, NCDOT Aviation, NCBELS and other state or local commercial drone operation and land surveying regulations, without a single reportable or unreportable incident. Being a responsible and professional organization, offering Photogrammetry and Surveying, including commercial drone aviation services, SDC carries the following insurance policies at a total annual expense of $38,113.56 for 2021.

1) Professional Liability Insurance (CNA)
    a. $2,000,000.00 aggregate limit per policy year, annual premium $5,864.00.
2) Commercial General Liability Insurance (Acord)
    a. $2,000,000.00 general aggregate limit per policy year, annual premium $3,130.00.
3) Automotive Liability (Acord)
    a. $1,000,000.00 combined single limit per policy year, annual premium $2,421.66.
4) Umbrella Liability (Acord)
    a. $4,000,000.00 aggregate limit per occurrence, annual premium $1,650.00.

5) Workers Compensation and Employers Liability (Acord)
    a. $1,000,000.00 per accident, per employee, annual premium $3,355.90
6) Aviation Insurance Policy Unmanned Aircraft Systems (Global Aerospace)
    a. $2,000,000.00 personal injury, annual premium $956.00.
    b. $255,000.00 hull coverage, annual premium $20,736.00.

Using a drone as an optional aviation tool for our Photogrammetry and Surveying operations hasn't eliminated our use of fixed wing or rotor wing aviation platforms for airborne imagery and LiDAR data acquisition. We only implement drone imagery and LiDAR acquisition into our project technical plan when it makes practical sense, typically the deciding factors being the location of the project site in relation to regulated or controlled airspace, the area size of the project, the distance we have to mobilize to the project site and the physical conditions of the site.

Photogrammetry is a very complicated and ever evolving science and industry, with challenges and difficulties that require highly trained and skilled staff, most often certified or licensed by a professional organization or regulatory Board. Adding unmanned autonomous vehicles (UAVs), non-metric sensors and Structure from Motion (SfM) Photogrammetry post processing software makes Photogrammetry even more complicated and difficult compared to using manned aviation platforms, metric sensors and traditional Photogrammetry software solutions that include more robust statistical analysis for post processing and 3D stereo viewing for data collection, data validation and quality control.

In our case, implementing a drone into our imagery and LiDAR acquisition workflow is not "cutting edge", or a "technical innovation", it's simply another means, or aviation tool, we use to collect airborne imagery and or LiDAR for our Photogrammetry project technical plans and workflows. Following is an outline for a typical Photogrammetry Project, be it UAS, fixed wing or rotor wing aviation platforms.

1) Project Technical Planning and Consulting (PLS, ASPRS Certified Photogrammetrist)
    a. Assess Client needs and objectives.
    b. Evaluate project technical and product requirements, scope of work (SOW).
    c. Flight and ground control planning.
    d. Cost estimating, technical and cost proposal development.
    e. Client consultations and or negotiation.
    f. Technical and cost proposal acceptance, contract execution.
2) Ground Control Survey (PLS, PLS Intern)
    a. Final control planning, refine project control point distribution and point locations.
    b. Research existing geodetic control, USGS and or State Geodetic Survey Agencies.
    c. Mobilize field crew and equipment to the project site.
    d. Select precise control point locations in the field, monument and pre-mark (target).
    e. Use conventional, Global Positioning Systems (GPS) surveying methods to obtain accurate horizontal and vertical coordinates for each control point.
    f. Select precise check point locations in the field, monument and pre-mark (target) them if they'll be enabled as control points for final post processing.
    g. Use conventional, Global Positioning Systems (GPS) surveying methods to obtain accurate horizontal and vertical coordinates for each check point.
    h. If using a Real Time Network (RTN), Real Time Kinematic (RTK) GPS survey methods, visit each control and or check point a minimum of two times for redundant measurements.

i. If using conventional survey methods, GPS base station with rover RTK-GPS or static GPS point occupation, post process field data using OPUS and or Manufacturer specific survey post processing software.
j. Output final ground control and check points in the project designed coordinate system using the appropriate horizontal datum, vertical datum and units.
k. Prepare Ground Control Surveys Report, signed and sealed by the PLS in responsible charge of field survey operations.

3) Airborne Imagery and LiDAR Acquisition (PLS, FAA Commercial Piot, Part-107 Certified Remote Pilot, Sensor Operator and or Observer).
   a. Final flight planning, review planned flight lines, forward or side overlap, altitude of operations, all other imagery and or LiDAR collection parameters, ensure regulatory compliance and public safety. For UAS, final flight planning includes selecting the launch and retrieve location for the drone.
   b. Assess airspace for restricted flight zones, submit waiver applications FAA approval, if required.
   c. Pilot safety check, FAA NOTAMs, TFRs and Aircraft Safety Alerts.
   d. Assess weather and wind forecasts and conditions, day of mission.
   e. Mobilize crew and equipment to the project site.
   f. For UAS, assess current site conditions to assure FAA Part-107 compliance and public safety. For some project sites, this requires flying a scout drone and collecting video which is reviewed and assessed in the field.
   g. For UAS, check ground control and or check points to ensure all are pre-marked prior to imagery acquisition, repair or replace targets as necessary.
   h. For UAS, to reduce GPS baseline distances, locate geodetic or local project benchmark for base station GPS occupation, collection of GPS baseline for drone exterior orientation (EO) trajectory data post processing. For some projects, CORS or SmartBase software post processing offer alternate base station options when required. Perform base station setup and begin collecting statice GPS.
   i. For UAS, assess and finalize drone launch and retrieve location, obtain permission if necessary.
   j. For UAS, prepare drone and payload, conduct preflight equipment and safety checks following documented operation and safety procedure checklists.
   k. For UAS, launch the drone, acquire imagery and or LiDAR, maintaining visual line of site with the drone. Land the drone, exchange batteries, launch drone for additional lifts, if required to complete acquisition.
   l. For UAS, review and verify ground control survey data, base station data, imagery and or LiDAR data acquired during the mission before leaving the project site, assuring complete data sets, no corrupted or incomplete files.
   m. Mobilize crew and equipment back to the hangar or office for field data transfer and post processing.

4) Airborne Imagery and LiDAR Post Processing (PLS, PLS Intern, Skilled Photogrammetric or LiDAR Technician)
   a. For large format metric digital airborne image sensors with multiple sensor heads or cameras, raw image data collected by the sensor system must be post processed, outputting exploitation images, typically 3-band (RGB) color, in some cases 4-band (RGBIR) color or false color infrared depending on which bands are used to display the images. The post processed exploitation images, 3 or 4 band, are used for subsequent photogrammetric processing and product development.

b. For UAS, images collected by the sensor system don't require supplementary post processing. Exploitation images, typically 3-band (RGB) color, are ready to use for subsequent photogrammetric processing and product development directly from the sensor data storage device.
c. Submit and post process base station data using OPUS for corrected positioning based on a minimum 2-hour static GPS collection.
d. Post process GPS base station data for exterior orientation (EO) trajectory data.
e. For UAS, post process preliminary orthoimage composite using SfM Photogrammetry. This preliminary orthoimage composite is used to assist LiDAR point cloud classification.
f. Post process raw LiDAR flight line data using EO data.
g. Isolate noise, assess LiDAR returns of the unadjusted LiDAR.
h. Post process LiDAR flight line data for relative orientation (RO), strip and bundle adjustments using ground control, creating a project LiDAR point cloud.
i. Based on terrain type, post process LiDAR point cloud by applying automated ground classification procedures. Output shaded surface, perform manual review and corrections to refine bare earth classification.
j. Post process statistical results for direct geo-referencing accuracy by comparing the bare earth classified LiDAR point cloud to the surveyed ground control points and or check points, generate LiDAR accuracy report.
k. Perform above ground LiDAR classifications based on ASPRS LAS Format 1.4.
l. Perform visual quality control inspection and refinement, assuring absolute classification and accuracy.
m. Post process final project colorized LiDAR point cloud.
n. Prepare LiDAR Post Processing Report, signed and sealed by the PLS in responsible charge of LiDAR field operations and post processing.

5) Aero-Triangulation Post Processing (PLS, PLS-Intern, Skilled Photogrammetric Technician)
   a. AT strip and block preparation and project setup, organize and format if necessary: EO trajectory data, surveyed ground control and checkpoint data, exploitation imagery and camera data files.
   b. Import all required data into the AT Post Processing software, setting up individual strips and a composite AT block. Identify and enter specific project post processing parameters based on the project technical requirements and SOW.
   c. For projects that require a high level of accuracy, manually select and measure 2-ray and 3-ray pass points within individual strips (flight lines). A minimum of six, 3-ray pass points are required within the stereo overlap region of two consecutive exploitation images in a flight line to ensure measurement geometry and relative orientation (RO).
   d. For projects that require a high level of accuracy, manually select and measure 4-ray, 5-ray or 6-ray tie points between the side overlap regions between strips (flight lines). A minimum of two, 6-ray pass points are required within the stereo overlap region of two consecutive exploitation images and two adjacent flight lines to ensure measurement geometry and RO.
   e. For UAS, or projects that require lower levels of accuracy, conduct automatic or semi-automatic pass and tie point generation, often called auto-correlation, or SfM Photogrammetry. This type of automated process for pass and tie point geometry often requires visual review and supplemental manual measurements to refine the strips and block for successful RO, regardless of accuracy requirements.
   f. Manually measure the surveyed ground control in reference to where it appears in the imagery.

g. Post process the AT block for RO applying predetermined weigh factors for the image rays within the defined AT project parameters. Perform statistical analysis, review and remeasure image rays that fall outside tolerances set within the defined AT project parameters, refine the measurement rays util the overall RO sigma is within the defined AT project parameters for image measurement Root Mean Square Error (RMSE).
h. Post process the AT block for absolute orientation (AO) by enabling the EO trajectory data, surveyed ground control and or check points in the post processing solution, applying predetermined weight factors within the defined AT project parameters. Perform statistical analysis, review and remeasure image rays that fall outside tolerances set within the defined AT project parameters, refine the measurement rays util the overall AO sigma is within the defined AT project parameters for image measurement and ground control Root Mean Square Error (RMSE).
i. Finalize AT block AO bundle adjustment, densify control, apply bulk orientation to apply final RO, AO and single photo resection parameters to the final EO data and stereo models for 3D stereo feature collection.
j. Prepare AT Post Processing Report, signed and sealed by the PLS in responsible charge of AT measurement and post processing.

6) 3D Stereo Mapping (PLS, PLS-Intern, Skilled Photogrammetric Technician)

a. Stereo model and data collection setup, organize and format if necessary: final AT data files and stereo exploitation imagery.
b. Import all required data into the 3D Stereo Photogrammetric data collection software, setting up stereo models and CAD workspace environment. Identify and enter specific project data collection parameters based on the project technical requirements and SOW. Create project mapping limits and stereo model boundaries within the CAD workspace environment.
c. Cursory review of all project stereo models, visiting each surveyed control point, taking manual readings at each point to ensure horizontal and vertical accuracy comparing the actual field survey coordinates to the coordinates generated by the final AT AO solution, measured by the Technician within the 3D stereo models prior to feature data collection.
d. Manually measure and digitize 3D planimetric features based upon the project technical requirements and SOW: structural, transportation, utility, vegetation and hydrographic feature classes, any planimetric or cultural feature visible in the stereo imagery.
e. LiDAR data quality control, manual review for vertical accuracy in comparison to the 3D stereo model surface. Use automated and manual procedures to remove LiDAR points from conflicting structural and hydrographic features, as well as other 3D planimetric features included in DTM processing.
f. Manually measure and digitize supplemental 3D digital terrain model (DTM) features based upon the project technical requirements and SOW: supplemental DTM break lines and elevation points where LiDAR points don't adequately define the terrain surface. Use automated and manual procedures to remove LiDAR points from conflicting DTM features.
g. Generate temporary contours, measure and digitize supplemental spot elevations: tops, bottoms, saddles, areas where contours are spaced apart further than the project parameters allow for.
h. Detailed 3D stereo quality control review to ensure complete planimetric content, DTM accuracy and contour integrity.

i. Create final 3D mapping files for product development: separate 3D planimetric feature and 3D DTM feature files.
j. Post process the final DTM file: quality control for duplicate points or crossing break lines, export final contours and required surface files, XML or TIN.
k. Combine final 3D mapping files for product delivery: final planimetric and topographic feature file, final DTM feature file and final DTM surface file, in appropriate CAD, GIS, XML or TIN formats.
l. Develop digital mapping metadata.

7) Orthoimage Post Processing (PLS, PLS Intern, Image Analyst, Skilled Photogrammetric Technician)
    a. Perform global exploitation image radiometry adjustments, correcting the project exploitation images for dynamic range, tone, color, contrast and brightness.
    b. Orthoimage project and workspace setup, organize and format if necessary: final AT data files, final project DTM or digital elevation model (DEM) surface files and exploitation imagery.
    c. Post process preliminary exploitation orthoimages for visual quality control review and seam line development.
    d. Develop seam lines using automatic, semi-automatic or manual seam line digitizing techniques.
    e. Visual seam line quality control review using image transparency functions and custom MDL utilities to avoid seam line conflicts and DTM or DEM blunder detection.
    f. Edit seam lines, correct DTM or DEM blunders.
    g. Post process final exploitation orthoimages for mosaic post processing.
    h. Import final seamlines and exploitation orthoimages in the project workspace, process seam line polygons and exploitation orthoimage polygon assignments.
    i. Mosaic post processing, including secondary image color and tone matching adjustment, combining multi-resolution imagery if required, creating a seamless transition and visually consistent result for GeoTIFF output as one composite orthoimage or predetermined orthoimage tiles.
    j. Internal macro quality review, visual inspection for image artifacts, seam line blunders or other image distortion introduced during the mosaic post processing.
    k. Perform macro quality review corrections.
    l. GeoTIFF product development: modify GeoTIFF header if required, output specific orthoimage mosaic or tile formats… TIFF, MrSID, JPG2000, or other image formats.
    m. Develop orthoimage metadata.
    n. Prepare Orthoimage Post Processing Report, signed and sealed by the PLS in responsible charge of AT measurement and post processing.

8) Product Deliver, Project Conclusion (PLS, ASPRS Certified Photogrammetrist)
    a. Product delivery to the Client via FTP or other electronic data transfer.
    b. Draft and submit a Project Certification Letter or Airborne Surveys Report detailing the tasks, procedures, equipment, software, technical specifications, survey standards, statistical analysis for horizontal and vertical accuracy, signed and sealed by the PLS in responsible charge, overseeing all project tasks.

The outline above is an example of a typical Photogrammetric Survey Project, the task descriptions are brief and non-technical in nature, true technical documentation of a Photogrammetry, applications, theory and workflows, could take hundreds of pages.

Photogrammetry text books are extremely technical, outlining the complex and arduous mathematics and principals Photogrammetry is based upon, fundamental changes in photogrammetric theory or practice due to technological changes such as widespread adoption of digital imagery and the emergence of separate fields with strong photogrammetric components, such as geographic information systems (GIS) and remote sensing. These text books are typically for graduate-level courses at the Master's level.

Some Photogrammetry projects can be far more complex than outlined above, some could be less complex than outlined above. Project scope and workflow can vary widely from project to project however, any Photogrammetric project, regardless of complexity, requires extensive expertise, knowledge and skill to ensure survey integrity and accuracy, meeting or exceeding applicable regulatory standards, conducted in a professional and ethical manner.

For the past 25 years SDC has thrived as a Photogrammetry, Surveying and Geospatial firm here in NC, serving a wide variety of private and government Clients. Since licensure in 1999 with NCBELS, for the past 22 years, both myself as a Professional Land Surveyor and SDC as a Professional Corporation, our success in the industry hasn't been impeded in any manner through professional regulatory compliance. If a poll was taken of the other 4,370 licensed Professional Firms, 2,336 licensed Professional Land Surveyors, and 29,585 licensed Professional Engineers in NC, I'm sure all or the majority would agree that regulatory compliance isn't cumbersome or an inconvenience, it's an asset, and ensures the public is protected from malpractice.

Being licensed by NCBELS, both as an individual and a corporation, assures our clients and the public that we've met specific standards for education, expertise and experience. With professional licensure comes obligations for professional conduct and ethics, and the requirement to maintain proper insurances for business liability, aviation operations and professional liability - errors and omissions, which protects the public from malpractice. Licensure with NCBELS and other regulatory agencies has afforded us business opportunities and allowed us to be successful by validating our credentials.

For the past three years, implementing drones and establishing an internal UAS program hasn't increased the number of projects we've been awarded compared to years prior to implementing drones, our gross annual revenue has remained somewhat consistent over the past three years compared to previous years. The only change that has occurred for us is we're using the UAS for projects that we'd have utilized a fixed wing or rotor wing aircraft in the past, which really isn't a change if you consider a drone as just another aviation tool.

The projects we fly using the UAS are typically 150 acres or less, are within a reasonable distance from our office, or have specific requirements for horizontal or vertical survey accuracy that can only be equaled by conventional ground survey methods. In some project cases, the Client's expectation for horizontal and vertical accuracy is 0.05' for clearly defined features and non-vegetated surfaces, 0.1' vertical accuracy for vegetated surfaces.

Photogrammetry - Aerial Surveying - Topographic Surveying Regulated in North Carolina.

The North Carolina Legislature designated the practice of Land Surveying as a profession. *See* N.C.G.S. § 89C-3(7)(a).

“Land surveying encompasses a number of disciplines including geodetic surveying, hydrographic surveying, cadastral surveying, engineering surveying, route surveying, **photogrammetric (aerial) surveying, and topographic surveying**.” *See* N.C.G.S. § 89C-13(b).

The practice of land surveying includes the following. *See* N.C.N.C.G.S. § 89C-3(7):

1) Locating, relocating, establishing, laying out, or retracing any property line, easement, or boundary of any tract of land;
2) Locating, relocating, establishing, or laying out the alignment or elevation of any of the fixed works embraced within the practice of professional engineering;
3) Making any survey for the subdivision of any tract of land, including the topography, alignment and grades of streets and incidental drainage within the subdivision, and the preparation and perpetuation of maps, record plats, field note records, and property descriptions that represent these surveys;
4) Determining, by the use of the principles of land surveying, the position for any survey monument or reference point, or setting, resetting, or replacing any survey monument or reference point;
5) Determining the configuration or **contour** of the earth’s surface by measuring lines and angles and applying the principles of mathematics or **photogrammetry**;
6) Providing geodetic surveying which includes surveying for determination of the size and shape of the earth both horizontally and vertically and the precise positioning of points on the earth utilizing angular and linear measurements through spatially oriented spherical geometry; and
7) Creating, preparing, or modifying electronic or computerized data, including land information systems and geographic information systems relative to the performance of the practice of land surveying.

The purposes of Regulating Land Surveying in North Carolina

The Act provides that “in order to safeguard life, health, and property, and to promote the public welfare, the practice of engineering and the practice of land surveying in this State are hereby declared to be subject to regulation in the public interest.” *See* NC G.S. § 89C-2.

In my opinion, Land Surveying and Photogrammetry are regulated in the State of NC to protect the public, individuals and businesses, from negligence, incompetence, professional misconduct or any other form of malpractice in the performance of services within the profession.

Furthermore, Land Surveying and Photogrammetry as a profession, is not “artistic impression” protected under the First Amendment. Art or artistic impression is for entertainment purposes, while surveying is providing useful information for a functional use.

Relying on untrained and unskilled amateurs to recognize any of the multiple varieties of problems or deficiencies that can arise from the measurements, computations or use of tools for the survey profession to create useful survey data, could be catastrophic to the outcome of a project and harm the public at large who relies on the accuracy and fidelity of this information.

Through proper education, training and years of practice under the guidance of others, along with regulation for standards of practice, the Professional understands the irregularities that occur within the practice of the profession and has the experience and expertise to avoid them, producing repeatable measurements and useful survey data, capable of being vetted by other Professionals as verification of the results.

Regulation of Land Surveying through the development of an inclusions and exclusions list.

The Board actively updates and publishes policies to include or exclude activities that fall within, or outside the definition of the practice of land surveying as defined by N.C.G.S. § 89C-3(7).

From April, 2008 until October, 2011, in coordination with the NC Geographic Information Coordinating Council (GICC), the Board codeveloped GIS Inclusions/Exclusions Guidelines, these guidelines assist in determining if features or items of data are included or excluded from the definition of Land Surveying in N.C.G.S. § 89C-3(7). https://www.ncbels.org/wp-content/uploads/2019/03/gisinc_excl.pdf

While it is true that the guidelines are based upon elements that often show up in GIS databases, it is meant to use those as items representative of what may come into question as to whether it is within the definition of Land Surveying in N.C.G.S. § 89C-3(7), and requires a PLS. The statement at the top of the guidelines describes the authoritative purpose that it is to be relied upon by the public for the location and dimension data or is given to some stated accuracy. If so, then it is land surveying data.

Specific Issues Raised in the Complaint

A. "Capturing aerial images on behalf of paying clients and using orthomosaic software to stich those aerial images together to form orthomosaic maps."

In my opinion, this could be a gray area because of the use of the word "map" and whether or not the orthomosaic is printed or in a digital format.

The word "map" may imply or be interpreted as a survey, or document that is corrected for distortion, is scalable and can be used for accurate measurements.

If the document was printed, also called "hard-copy", and didn't include a reference grid, scale bar, north arrow, title block, etc., basically just a printed picture, this would not be regulated.

If the orthomosaic is in a digital format such as Adobe PDF and doesn't include georeferencing information in the file header as metadata, in my opinion, this would not be regulated. If the orthomosaic was any other digital format such as TIFF, TIFFJPG, JPG2000, MrSID, etc., and didn't include georeferencing information in the file header as metadata or accompanied by a separate georeferencing metadata file, in my opinion, this also would not be regulated.

If the orthomosaic is in a digital format such as TIFF, TIFFJPG, JPG2000, MrSID, etc., and does include georeferencing information in the file header as metadata or is accompanied by a georeferencing metadata file, in my opinion, this would be regulated as it falls under the definition of Land Surveying within N.C.G.S. § 89C-3(7).

B. "Creating marketing images of land on behalf of paying clients and drawing on those images lines indicating the approximate position of property boundaries."

In my opinion, this would not be regulated, as long as the marketing images are printed with no reference grid, scale bar, north arrow, title block, etc., Or, are in a digital format with no georeferencing information in the file header as metadata, or accompanied by a georeferencing metadata file.

A client could just as easily use screen capture software to create the same image with boundaries from a County GIS website although, these types of websites include disclaimers the User must acknowledge and agree to, and the client wouldn't be paying a fee for the image.

C. "Capturing aerial images of land and structures (along with location data, coordinates, elevation data, and volume data) and making those images and that data available to paying clients."

In my opinion, this would be regulated as it falls under the definition of Land Surveying within N.C.G.S. § 89C-3(7).

D. "Capturing aerial images of and data about land and structures; processing those images and data to create 3D digital models of land and structures; and making those 3D digital models available to paying clients."

In my opinion, this would be regulated as it falls under the definition of Land Surveying within N.C.G.S. § 89C-3(7).

Mark S. Schall
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Mark S. Schall, CP, PLS, PPS, SP

November 26, 2021______________________
Date

SDC RESUME

Name & Title: Mark S. Schall Chief Professional Officer

Years of Experience: With This Firm: 25 With Other Firms: 17

Education:

- High School Diploma: Northmont Senior High School, Clayton, OH
- 437.5 Hours of Continued Education required for Professional Registrations

Active Registrations & Affiliations:

- 1994 / Certified Photogrammetrist (CP# 950) ASPRS
- 1999 / North Carolina Professional Land Surveyor (L-4019)
- 2003 / South Carolina Professional Photogrammetric Surveyor (22679)
- 2010 / Virginia Surveyor Photogrammetrist (#75)
- North Carolina Society of Surveyors (NCSS)

Experience and Qualifications:

- 42 years of experience in Photogrammetry, Land Surveying, Remote Sensing and GIS.
- 33 years of project management and coordination experience.
- 33 years of production management experience.
- 22 years specialized experience as the Professional Land Surveyor (PLS) in responsible charge of projects awarded under contracts with North Carolina state agencies, most specifically NCDOT, CGIA, NCWRC & NCRC.

Project Experience and Qualifications:

- Project Manager and PLS in responsible charge for the 2016-2017 NCDOT 00157-Photogrammetric Services, Photogrammetry Limited Services Agreement, (LSA) 70000016554.
- Project Manager and PLS in responsible charge for the 2016-2017 NCDOT 00002-Aerial Imagery Services Limited Services Agreement, (LSA) 70000016550.
- Project Manager and PLS in responsible charge for the 2018-2020 NCDOT 00157-Photogrammetric Services, Photogrammetry Limited Services Agreement, (LSA) 70000018520.
- Project Manager and PLS in responsible charge for the 2018-2020 NCDOT 00002-Aerial Imagery Services Limited Services Agreement, (LSA) 70000018526.
- Project Manager and PLS in responsible charge for the 2021-2023 NCDOT Aerial Surveying Services Limited Services Contract, (LSC) 70000020804.
- Project Manager and PLS in responsible charge for the NC Coastal Orthoimagery 2016 Project, CO16.
- Project Manager and PLS in responsible charge for the NC Eastern Piedmont Orthoimagery 2017 Project, EP17.
- Project Manager and PLS in responsible charge for the NC Northern Piedmont and Mountains Orthoimagery 2018 Project, NPM18.
- Project Manager and PLS in responsible charge for the NC Southern Piedmont and Mountains Orthoimagery 2019 Project, SPM19.
- Project Manager and PLS in responsible charge for the NC Coastal Orthoimagery 2020 Project, CO20.
- Project Manager and PLS in responsible charge for the NC Eastern Piedmont Orthoimagery 2021 Project, EP21.